Northwest
Micro Mineral
Study Group

MICRO PROBE

FALL, 2013 **VOLUME XI, Number 8**

FALL MEETING . . . . .VANCOUVER, WASHINGTON

November 2, 2013 9:00 am to 5:00 pm

Clark County P. U. D. Building
1200 Fort Vancouver Way
Vancouver, Washington

Schedule for the day;

9:00 am Doors open at the PUD building for table set up. Helpers needed.

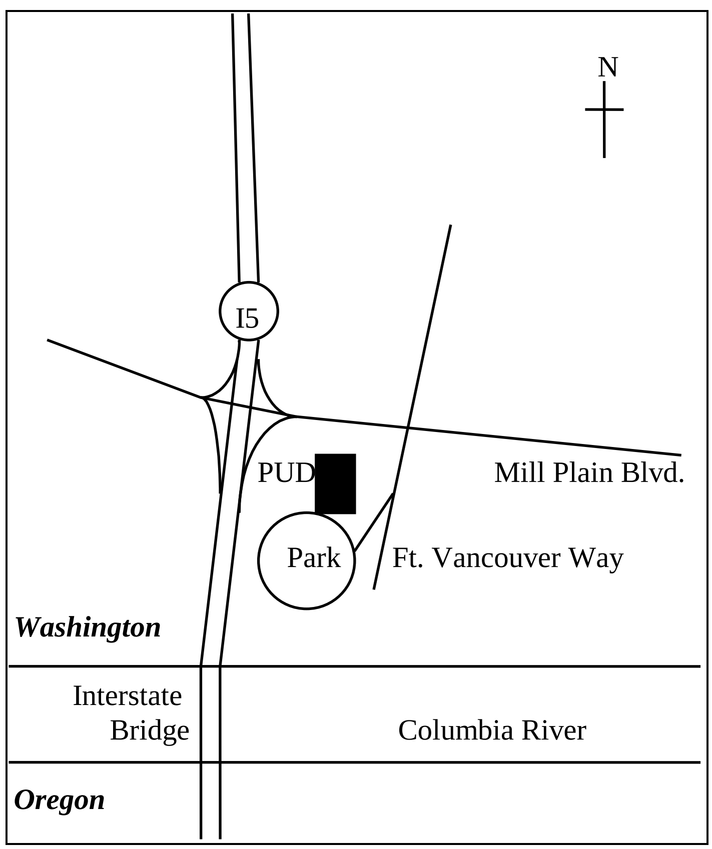
9:30 am Meeting starts: bring your microscopes, your special new finds, and spare material from past collecting trips to share and to trade. We will be looking forward to swapping stories and pictures with each other.

11:00am Business meeting. We have some changes to discuss. See Rudy's message on the next page for details.

12:00 noon Lunch potluck: Club provides sandwich makings (bread, meat, lettuce, cheese, dressings, and coffee, tea, cocoa). Please bring salads, chips, pop, nuts, chili, cookies, pie, or cake to add to the lunch.

1:30pm Pictures of minerals and collecting trips from our members. The computer will be set up to handle Powerpoint and other digital information. Bring yours for the rest of us to see and enjoy.

5:00 pm Dinner will be at the County Buffet in Vancouver. Please join us if you can.



President's Page Fall 2013

Gather your micro minerals, microscope or hand lens, and stories, and come to our fall meeting of the NWMMSG. I hope some of you have been busy collecting and studying your minerals. Bring some minerals to share with the group on the Free Mineral Tables, or for trading or selling. Clean out some of those boxes of minerals that have been collecting dust in your garage, pick out the keepers and bring the rest to the meeting.

We will have a potluck lunch. The club provides bread, sandwich spreads, lunch meat, cheese, lettuce, and some drinks. I always bring macaroni and potato salads. We need you to bring soft drinks, nuts, pastry/cookies/cake/pies, baked beans, and other stuff.

It has been some time now that I have been president of the group. It is time to step down and let someone else lead the group. We will have an election for president at this fall meeting. We need someone to volunteer.

A new mineral for The Golden Horn Batholith has been found. Actually it was found by Randy Becker in mid-1980's. The first chemical clues were found in 1999 and again in 2012; it was tentatively identified in 2012. Additional chemical work has now been completed confirming it as **Brannockite**, a lithium-potassium-tin silicate. This is the second known locality in the world for this mineral. Although we are unable to publish a report in the Micro Probe Newsletter until it is published in a professional magazine, we are able to describe it and show pictures of it at our fall meeting.

Bring your photos (digital) of minerals or trips you have and share them with the group during the program section of the meeting.

Rudy Tschernich

THE MICROPROBE

Published twice a year by the NORTHWEST MICROMINERAL STUDY GROUP

Donald G. Howard, editor
356 SE 44th Avenue
Portland, Oregon, 97215
e-mail: pogodh@hei.net

DUES: $15 per year per mailing address, payable at the Spring meeting or by mail to the Secretary/Treasurer:

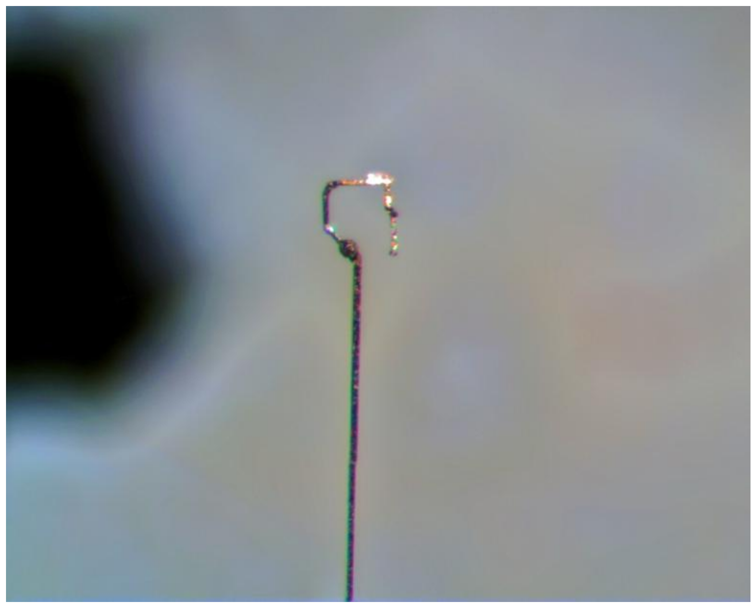
Patrick "Kelly" Starnes
1276 SE Goodnight Avenue
Corvallis, Oregon, 97333
e-mail: bikeklein@yahoo.com

Filiform Pyrite – Gradual Bends

Donald Howard

We are blessed with a number of collecting sites that have yielded fine crystals of filiform pyrite. These vary from the long, ultra-thin hairs that were found at Starvation Creek to the short, rather chunky one that have come from Yaquina Head. But by far the most fascinating ones are those that have right-angle bends.

Much thought and discussion has gone into the question of how filiforms are actually created in nature. The bends only serve to complicate the problem. For years, dislocations have been blamed for the formation. But the bends confound that picture, because dislocations cannot easily change direction. So further involved explanations have been put forth as to how one dislocation can come to an end and another begin at 90^{o}. The picture at right seems to illustrate our dilemma.

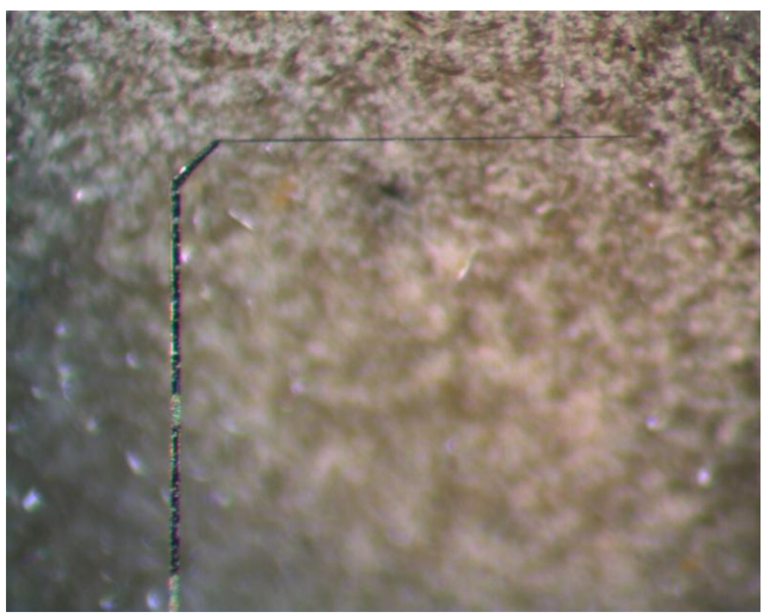


Filiform Pyrite, Clackamas River, Oregon

But wait! Look closely at the left side of that question mark. In addition to the sections at right angles, there is a diagonal section. Is that an accident?

Recently, Chuck Sweany passed on to me about a dozen specimens of Clackamas River material, all carefully mounted. Most have multiple right-angle bends. But at least three had something that I had never seen before – the bends were not the usual abrupt change of direction, but had instead sections that were at 45^{o} to the main portions of the crystal. I thought that this phenomenon was important enough to call your attention to it, and that just perhaps these sections would have a bearing on the discussion of formation mechanisms.

The next illustration very clearly shows that the usual bend from one [100] direction to the next has a section of crystal grown along the [110] direction. The thickness of the filiform indicates that it is growing from the bottom of the picture upward.

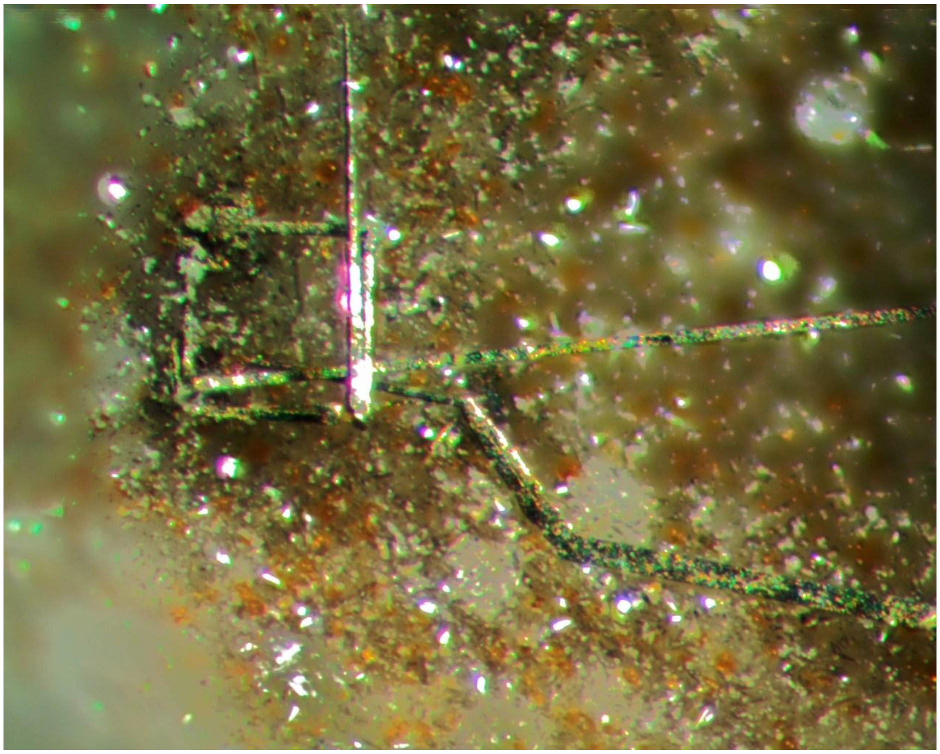


Filiform Pyrite, Clackamas River, Oregon

In past articles, (Microprobe X-3,pg2 ; XI-4,pg4) we have described an alternative explanation for the formation of filiforms, called Catalyzed Growth. In this model, a small particle of some sort acts as a catalyst to concentrate the material necessary to grow a crystal. The material subsequently begins to precipitate out at the contact between the particle and the substrate on which it is resting. As the new material forms, it lifts the particle. Continued precipitation at the contact then serves to grow the new crystal in a particular direction.

For pyrite and for native copper (see next article), the preferred direction of growth is along a cube axis [100]. Growth continues as long as the catalyst particle is not disturbed. If some external event, like a small earth tremor, shifts the particle without breaking contact, a new growth direction can occur. Presumably, if the shift is more than 45^o to one side, the growth will shift to another of the axes of the cube, and a right-angle bend will result. We would recognize as part of the model that the [110] is also a possible growth direction, just one not quite as energetically favorable as the [100]. If the shift is very nearly 45^o, the filament could grow in that direction instead, at least for a short while. In that way, we could form these transition regions.

Of course, the second shift could just as well return us to the original direction instead of completing the right-angle bend, so we should expect to see some filiforms with only a diagonal offset. Just that sort of behavior is visible in the lower center of the picture at right.

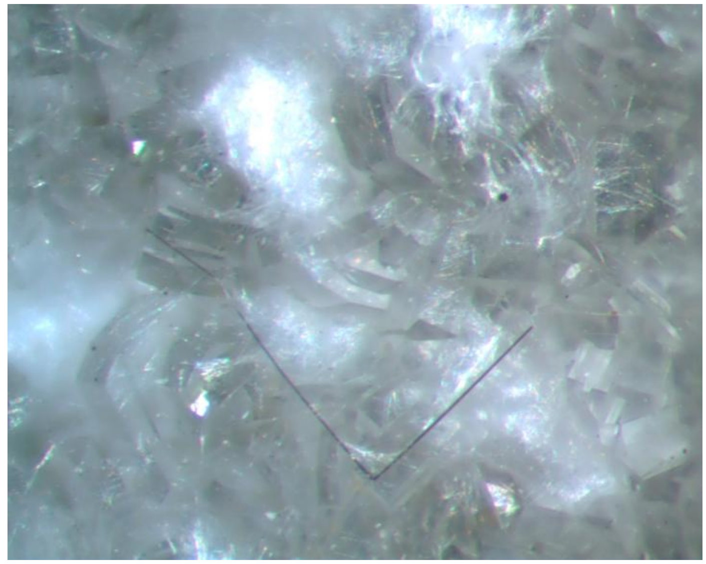


Filiform Pyrite, Clackamas River, Oregon

It is therefore very possible to include these diagonal sections in an explanation based on the Catalyzed Growth model. However, there are some other considerations that must be taken into account. In the laboratory prepar ations on which the model is predicated, the material to be concentrated is in the form of a vapor, that then dissolves in the small catalyst particle, which itself is in a fluid state. This presupposes elevated temperatures. The filiform ilmenite, to which the model was first advanced (Howard, 2010), matched those conditions. The resulting growth was probably very rapid, of the order of a few hours or days. Unfortunately, no bends were observed in the ilmenite filiforms, though there were bend seen in the laboratory experiments.

Pyrite is usually considered a low temperature mineral. The presence of clays and zeolites in the same cavities as the filiforms reinforces this assumption. Indeed, filiforms often appear to have formed on top of the clay or zeolite, as the illustration at the top of the next page shows. At low temperature, two of the conditions found in the usual description of the model of Catalyzed Growth are not present: the particle acting as a catalyst will be solid, not fluid, and there will be insufficient molecules of the growth chemical present in the vapor phase.

The condition that the catalyst be a fluid is because the growth material is supposed to dissolve in it. Is there a way that a solid particle could therefore be a catalyst? I think there is. In particular, a small zeolite particle would have large internal surface area combined with quite a high mobility of ions. Zeolites are noted for being able to selectively adsorb certain ions and concentrate them.



Filiform pyrite on clinoptilolite and erionite
Tunnel Beach, Seaside, Tillamool Co., Oregon

The problem of delivery is trickier. Vapor pressures would clearly be too low to be useful. It is tempting to propose delivery in aqueous solution, since water is known to be a solvent for most materials at some concentration or other. But it is very doubtful that Catalyzed Growth can occur in solution. The problem here involves Brownian motion. Molecules in a liquid are very close, and they are constantly in motion due to thermal energy. The constant random jostling of colliding molecules causes tiny particle to be driven around in an erratic manner. This jostling should quickly knock to catalyst particle off the end of the growing tip. Unusually large forces would be required to keep the particle in place, and these would be difficult to achieve in a liquid environment involving water.

So is there any other possible mechanism? Is it possible that transport could be achieved through surface diffusion? Here molecules would have enough thermal energy to shift along surfaces even though they do not have sufficient energy to free themselves from the surface to become a vapor. Ions of iron and sulfide would not easily start new layers on an existing pyrite crystal without the kind of growth step presented by dislocations, but could be incorporated into the ***end*** of a crystal where a particle sitting on that end provided the necessary stability to hold it in place. The catalytic particle would in effect provide the necessary lowering of energy required to nucleate new layers.

Is there any precedent that this might be a possible mechanism? Have you ever mounted up a nice native silver specimen, only to discover when you go back several weeks later to look at it that it has grown bristly hairs of acanthite, silver sulfide? The samples are dry, and the vapor pressure of silver is very low at room temperature, so surface diffusion must be involved. Moreover, sometimes this procedure happens and sometimes it does not. That is very reminiscent of the phenomenon of “whisker growth” on metals that eventually was explained by the mechanism of Catalyzed Growth. As metal surface cleaning improved, the formation of whiskers decreased since the necessary impurity particles on the surfaces had been removed. Of course, that suggests that the growth of acanthite on native silver could require some sort of tiny particles to act as catalysts???

The explanation of right-angle bends that Catalyzed Growth provides is a strong incentive to find the necessary conditions that fit low-temperature formation of filiform pyrite. I hope we are on the right track here.

References:

Howard, D.G., *“Hexagonal Filiform Minerals in Nature and in the Laboratory”*, Microprobe, Vol.X, #3, Pg2. (2006).

Howard, D.G., *“Filiform ilmenite crystals from Lemolo Lake, Douglas County, Oregon”*, N. Jb. Miner. Abh. 187/1, 97-99 (2010)

Howard, D.G., *“Twisted Crystals and Catalyzed Growth”*, Microprobe, Vol.XI, #4, Pg4. (2011).

Tubulite ???

Robert Woodside & Donald Howard

On March 26, Rob Woodside wrote me the following letter:

Hi Don,

Ty Balacko sent you a specimen many years ago. It was a metallic tube sitting on a quartz xl. You found it to be Boulangerite and we published your photo, Fig. 15 on pg 227, in Rare Sulfosalts from the Van Silver Mine, British Columbia.; Mineralogical Record, vol 31, pg 219- 229, May June 2000.

These Tubes were so rare and interesting, that I could not bring myself to beg the others to sacrifice any more than this one for analysis. Besides Boulangerite seemed like a no brainer even without analysis!!! How wrong I was!!!

If you have seen the front cover of the Italian type minerals book you will see similar tubes. It took me some months to notice this!!! Yves Moello described it then as a "silver Jamesonite" and a new mineral. Because of the Ag content I sent him a tube associated with Fizelyite and he replied Owyheeite! He used SEM and said there was too much Ag for tubulite, apparently the name given to the silver jamesonite http://www.mindat.org/min-42737.html In addition to the hairy Boulangerites that we x-rayed and probed at the GSC there were these tubes at Van Silver http://www.mindat.org/gallery.php?loc=5490&min=738 The previously mysterious red light you can see in a couple of the tubes is actually transmitted red light!!! Tubulite does the same and Moello thinks they are less than a micron thick. So I think I missed a new mineral in my zeal to protect specimens. I can remember pontificating that these Ag Pb Sb deposits had been analysed to death in the last couple of hundred years and it would be impossible to find anything new.

So I wonder if you still have that tube and its spectra. If so there should be a tiny Ag peak just above background, like the Fe peak in Jamesonite. You may have the world's first discovered tubulite.

Thanks again for the photo.

Cheers, Rob

I replied:

Dear Rob,

Thank you so much for calling my attention to this interesting puzzle. I am thrilled to think that we may have another rare mineral in our midst.

I did not answer immediately because I was going through past records looking for the data on the tubes. I am sorry to say that I have not managed to find it yet, but I think I know enough about the process to pretty much patch things together to explain the outcome. To start with, I was using an EDAX attachment to an SEM. This collects all generated x-rays simultaneously, so it is lots faster, but is not very quantitative, and the resolution is not nearly as great as on a real microprobe that uses a monochromator crystal detector. This means that peaks of various elements lie on top of each other. For instance, lead, molybdenum and sulfur all give peaks at about the same energy. While lead and molybdenum have additional peaks elsewhere to help identify them, sulfur does not. So sometimes we end up guessing that a peak is higher than we would have expected and infer that sulfur was present also. The antimony is well separated and generally stands out; at least it does in something like boulangerite.

As you said, we thought we knew that this stuff had to be boulangerite, so the primary purpose of the time was to get good pictures. In order to do that, the sample has to have a thin conducting coating to carry away the electrons and prevent charge buildup that gives distortions and blurring, and may cause flairs in the picture. The two main coatings I am aware of people using are carbon and an alloy of gold/palladium. The trouble with the carbon is that there is not good way to remove it later, so the sample gets sacrificed. So I used a coating of Au/Pd that was sputtered on. The disadvantage here is that there will then be weak peaks of gold and paladium. Gold is no problem; its peaks are well separated. But the peaks from palladium (generally a set of about 4 close together) lie just a bit above the S/Mo/Pb position. Usually this is not a problem, but for the case in point, silver has a Z one greater than palladium. So if a little bit of silver produces peaks, they would lie right on top of the palladium ones and be masked to the point that they would not have been noticed.

The remedy would be to redo the analysis without the coating. That really would not be a problem. And I still have the specimen. BUT.....

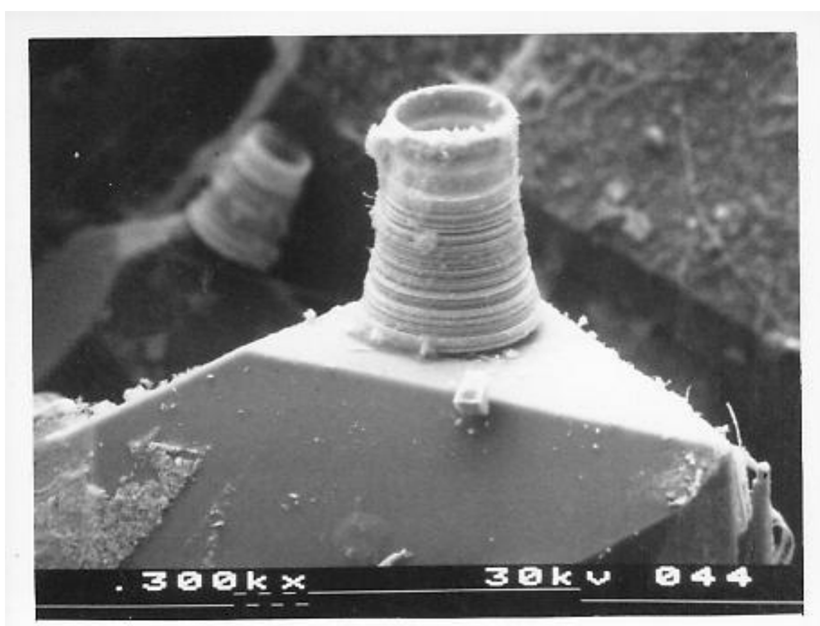
I mentioned that the Au/Pd can be rather easily removed from most specimens. How? You just rinse the piece for a few minutes in a solution of sodium cyanide and then in clear water. The solution quickly dissolves palladium and gold ..... and copper and silver and a few other metals. If these tubes are as thin as suggested, I believe the silver would have been wisked away and no longer be present even if it had been there to start with. So it would have to be done on a virgin specimen. That might be possible. Currently, the machine has mechanical problems, and I am not sure it is working well enough to do the required survey. It does have a better detector, and the last few times I have been able to use it, I have done so without any coating. That is mostly because we can no longer buy the polaroid film necessary to take the pictures, so the coating isn't really needed.

I am still not convinced that we are dealing with the same thing as the European material. The pictures on Mindat look to me like smooth tubes, while those from Van Silver are much more like a coil of wire. I am attaching another of the pictures, in which it might be an illusion, but it sure looks like one of the hairs winding the coil comes off and goes straight. I suppose the only real test is the presence or absence of silver. Your comment about the tube you sent being owyheeite is interesting. Do you suppose there are owyheeite tubes possible as well? I wonder just how stoichemetric the chemistry is. The formula for tubulite leaves me wondering if the silver content could be somewhat variable. Two parts Ag to 22 parts Pb does not sound to me like something governed by site in a crystal structure. But then I could be wrong about that.

Suggestions about what to call this stuff? I think I will leave my label alone until we have some sort of agreement on what we have. If you can come to some sort of agreed conclusion, you might consider writing up a page or two about the matter to put in our twice-yearly publication, the Microprobe. I'd be ready to help any way I can. I am sure that other members of our group have gotten pieces from Ty and would be very interested.

Thank you again for thinking of me and sharing your insights. I look forward to hearing more about the matter in the future. Good collecting to you! Don

The more I think about this, the more convinced I am that he is right. I am comfortable enough with the identification that I intend to change my labels.
Don



Tubulite ? on Quartz *Van Silver, British Columbia*

New Minerals from the Esquire Claims, Fresno County, California

Donald Howard

There are several spots in the Sierra east of Fresno and south of Yosemite National Park where sanbornite occurs, and with it a number of rare barium-containing minerals. Sanbornite, $Ba_2(Si_4O_{10})$, is colorless to white and occurs in sheets, often several inches across. The deposit near Eagle Peak, El Portal, Mariposa County is the type locality for sanbornite. That deposit is also the type locality of titantaramellite and fencooperite.

Sanbornite is also a primary mineral at some claims held by Robert Walstrom in Fresno County. Thanks to his efforts, several new minerals have been identified and named from these deposits as well. The type minerals described earlier include:

From ***Big Creek***, near Pine Flat Lake

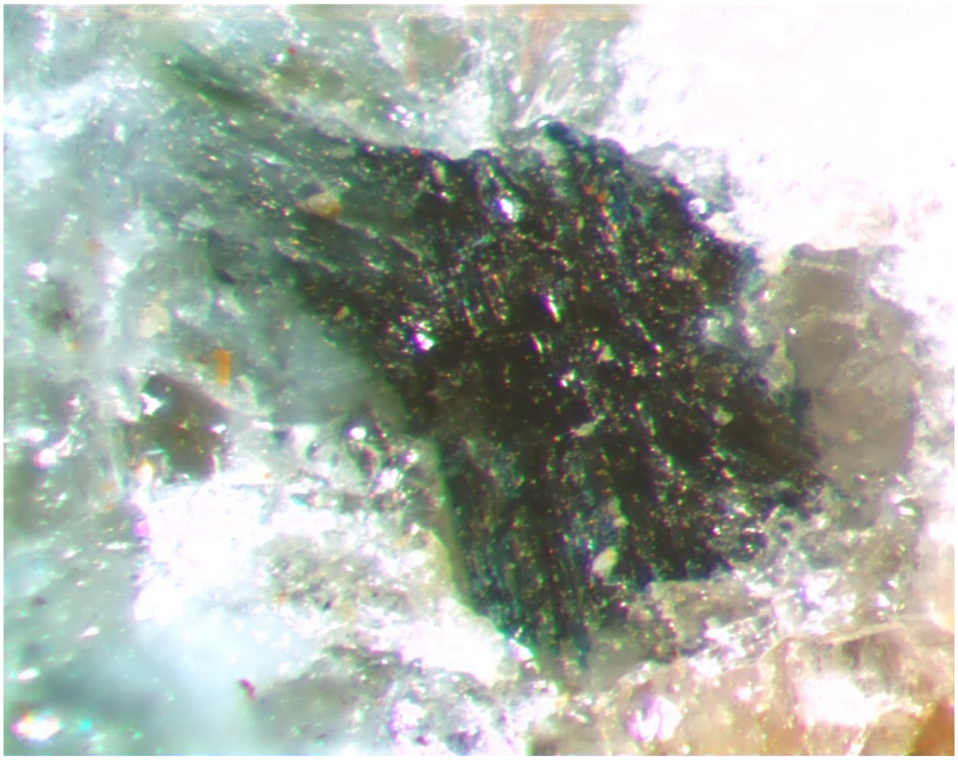
Esquire #8 Claim		
Devitoite	$[Ba_6(PO_4)2(CO_3)][Fe^{+2}_7(OH)_4Fe^{+3}_2O_2(Si_4O_{12})_2]$	*black, firbous*
Ferroericssonite	$BaFe^{+2}_2Fe^{+3}(Si_2O_7)O(OH)$	*dark red, micaceous*
Esquire #7 Claim		
Alforsite	$Ba_5(PO_4)_3Cl$	*colorless*
Bigcreekite	$Ba(Si_2O_5) \cdot 4H_2O$	*colorless, pearly*
Muirite	$Ba_{10}Ca_2MnTiSi_{10}O_{30}(OH,Cl,F)_{10}$	*orange*
Titantaramellite	$Ba_4(Ti,Fe^{+3},Fe^{+2},Mg)_4(B_2Si_8O_{27})O_2\ Cl_{0\text{-}1}$	*dark brown blades*
Verplanckite	$Ba_{12}(Mn,Fe,Ti)_6(Si_4O_{12})_3(OH,O)_2Cl_9(OH,H_2O)_7$	*yellow brown*
Walstromite	$BaCa_2Si_3O_9$	*white, fluorescent orange*

From ***Rush Creek***, near Shaver Lake

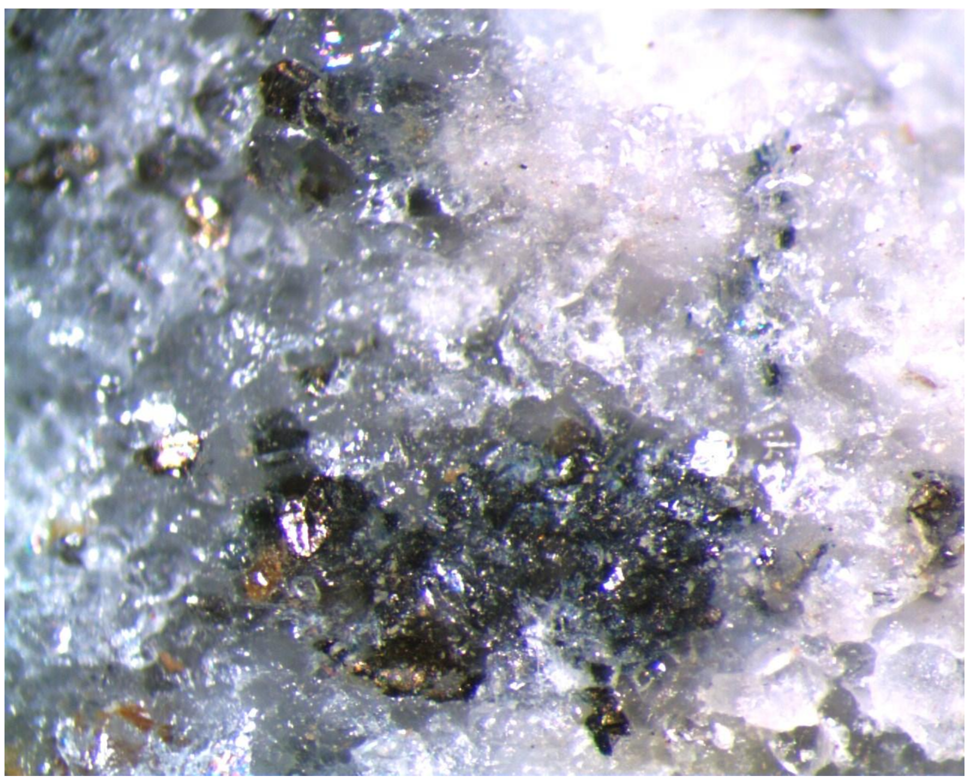
Esquire #1 Claim		
Kampfite	$Ba_6[(Si,Al)O_2)]_8(CO_3)_2Cl_2(Cl,H_2O)_2$	*pale bluish gray*
Krauskopfite	$BaSi_2O_4(OH)_2 \cdot 2H_2O$	*colorless, pearly*
Macdonaldite	$BaCa_4Si_{16}O_{36}(OH)_2 \cdot 10H_2O$	*white, acicular, radial*
Traskite	$Ba_9Fe^{+2}_2Ti_2(SiO_3)_{12}(OH,Cl,F)_6 \cdot 6H_2O$	*reddish brown*
Other unusual minerals found there include:		
Bazirite	$BaZrSi_3O_9$	*white, fluorescent blue-white*
Benitoite	$BaTiSi_3O_9$	*blue, flourescent blue-white*
Fresnoite	$Ba_2TiOSi_3O_7$	*bright yellow*
Gillespite	$BaFe^{+2}Si_4O_{10}$	*bright red, micaceous*

This year, Bob Walstrom presented two new minerals: cerchiaraite-(Al) and cerchiaraite-(Fe). The original mineral, cerchiaraite, is a manganese-containing barium silicate from Italy. In order to have the new minerals approved, it was necessary to rename this original mineral cerchiaraite-(Mn). Cerchiaraite-(Mn) is dark green in color, while both of the new minerals are very dark blue. All three are fibrous in nature.

Cerchiaraite-(Al)	$Ba_4Al_4Si_6O_{18}(OH)_7Cl$	from Esquire #1 Claim
Cerchiaraite-(Fe)	$Ba_4Fe_4Si_6O_{18}(OH)_7Cl$	from Esquire #8 Claim



Cerchiaraite-(Al) in Sanbornite
Esquire #1 Claim, Rush Creek, Fresno Co., California



Cerchiaraite-(Fe) with Pyrrhotite in Quartz
Esquire #7 Claim, Big Creek, Fresno Co., California

Micro Minerals of the Candelaria Mining District, Mineral County, Nevada

Kelly Starnes
1276 SE Goodnight Avenue
Corvallis, OR 97333

Introduction

In June of 1987, I was hired by NERCO Exploration Company as a junior exploration geologist at Candelaria Silver Mine, Mineral County, Nevada. The job put me in a fortunate situation where I could collect mineral specimens from the mine site and surrounding areas. Armed with a large lunchbox, and an interest in the micro minerals, I was able to collect from the mine and surrounding areas until my departure in July, 1991. I found a nice variety of minerals in the arsenate, carbonate, and phosphate families. Many of the exact locations where these minerals were found have been mined out, but there is potential in the district to produce more specimens. Access, however, is another issue. I have not visited the area since my 1991 departure, so I can only assume that the mine area is posted and gated.

Location

Candelaria Mining District is located in west central Nevada, approximately 130 miles southeast of Reno, Nevada; 55 miles southeast of the town of Hawthorne, Nevada; 62 miles west of Tonopah, Nevada, see Figure 1.

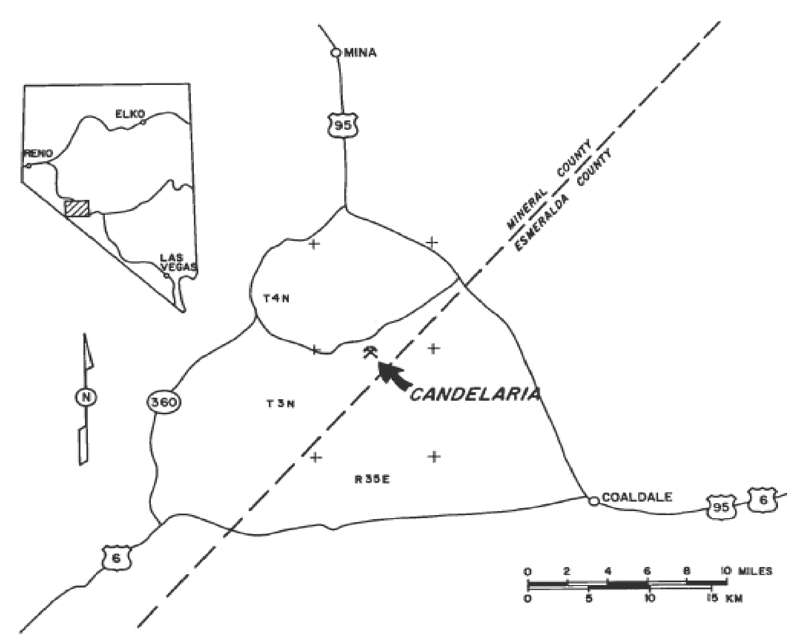


Figure 1 Location of Candelaria Mining District (from Moeller, 1988)

History

Silver veins were discovered in the Candelaria Mountains by a company of Spaniards in 1863 and a mining district was formed the same year. A settlement was founded, Columbus, five miles to southeast where water was found at the edge of an alkali flat, now called the Columbus Salt Marsh. Not until the middle of the 1870's did the district come into its own, but then, owing to the successful development of the Northern Belle mine, it became the most productive silver camp in Esmeralda

County and one of the foremost in Nevada. In April 1875, the Northern Belle began paying monthly dividends, and for a period of ten years it produced annually a million dollars in bullion.

A town was eventually founded near the mine and was named Candelaria in 1876. A water system was completed in 1882, which brought water from the White Mountains through a pipe line 27 miles long. In March of the same year the Carson & Colorado Railroad, a narrow-gage line, reached Candelaria by a branch from the main line near Belleville. In later years, after the discovery of Tonopah in 1900, the narrow-gage line was taken over by the Southern Pacific system, changed to a broad-gage line as far as Mina, 25 miles from Candelaria, and renamed the Nevada & California Railroad. The Mount Diablo mine became a heavy producer around this same time, and in 1883 it began paying its first dividends. The peak of the prosperity lasted from 1875 to 1886 or slightly beyond. The district declined rapidly after 1891. From that year until 1914, the occasional production figures are all less than $30,000 for a year's output of ore.

During the mid-1960's, interest in the district began again as several companies explored for large tonnage, bulk mineable silver deposits. In 1979, Occidental Minerals (Oxymin) built a cyanide plant and began mining the Lucky Hill and Mt. Diablo open pits. Oxymin poured their first doré bullion in 1980. In 1982, depressed silver prices forced Oxymin to suspend mining operations. In that same year NERCO Minerals Company (NERCO) acquired Oxymin's majority interest in the mine and restarted mining operations in early 1983 on additional reserves defined at the Mount Diablo and Lucky Hill pits. In 1985, NERCO began mining the Northern Belle pit. By 1987, NERCO was mining at a production rate of 5.5 million tons of ore per year from the Mount Diablo and Northern Belle pits. Mine production continued until 1989 for Northern Belle and 1990 for Mount Diablo, when once again low silver prices forced suspension of all mining operations. NERCO was subsequently taken over by AMAX Minerals, which was in turn acquired by Kinross. Kinross began mining in January, 1994, primarily from the Northern Belle pit and to a lesser extent, Mount Diablo, "J", and Georgine pits. Kinross ceased mining at the end of April, 1997. The mine was purchased from Kinross in 2001 by Silver Standard Resources, Inc. and no mining appears to be occurring at this time.

Geology

The oldest rocks in the district comprise the Palmetto Formation, an Ordovician age, deep water deposition chert-argillite-dolomite sequence, which is tectonically interleaved with stratigraphic slices of Devonian age limestone and calcarenite. This formation is a tectonic-stratigraphic equivalent of the Valmy and Vinini Formations of central Nevada and was emplaced along the Roberts Mountain Thrust fault during the mid-Paleozoic Antler Orogeny.

A younger sequence of Permian and Triassic age marine sediments, the Diablo and Candelaria Formations, was deposited unconformably on the Roberts Mountain allochthon. The Diablo Formation is a coarse grained siliclastic unit generally less than 30 feet thick. It, in turn, is overlain conformably by the early Triassic Candelaria Formation, an upward coarsening marine sequence, with a thickness of up to 3,000 feet. The Candelaria Formation has been divided into four members (Speed, 1984). Member 1 is the basal unit and is the principal host to mineralization at Candelaria. It consists of 200 to 250 feet of thin-bedded carbonaceous, calcareous mudstones; with thin limestone beds in the lower part; and a thin chert fragmental bed in the upper part. The upper members of the Candelaria Formation consist of thin-bedded mudstone in Member 2, bedded feldspathic sandstone in Member 3, and feldspathic mudstone and pebbly sandstone in Member 4.

The Golconda allochthon was structurally emplaced upon the Candelaria Formation during the lower Triassic Sonoma Orogeny. The Golconda allochthon in the Candelaria Hills consists of the Pickhandle Gulch Complex, a Mississippian- to early Triassic-age tectonic mélange that comprises the sole plate of the Golconda allochthon. The Pickhandle Gulch Complex consists of a 1,600 foot thick structurally disrupted sequence with slices and blocks of Mississippian to early Triassic sediments within a serpentinite complex, and represents the emplacement from the north of the Sonoma volcanic arc. The structural base of the complex is marked by the Pickhandle Gulch Thrust fault, a local expression of the Golconda thrust system. A related structural zone, the Lower Candelaria Shear zone or "LCS," occurs in the lower part of the Member 1 of the Candelaria Formation and is the main host for mineralization in the district.

A series of stocks and small plutons of intermediate composition were emplaced during Cretaceous time in west-central Nevada. In the Candelaria area, these rocks range in composition from granite to diorite, fine grained to porphyritic, and are referred to as the "mine sequence intrusives." These intrusions occur as individual sills and dikes focused along the east-west striking and north dipping trend of thrust faulting of the lower Candelaria Formation. Sills up to 150-feet thick and 2,500 feet long occur primarily along the Pickhandle Gulch Thrust at the upper contact of the Candelaria Formation, in the lower Candelaria Formation near the contact with the Diablo Formation, and variably within Member 1 and the lower part of Member 2 of the Candelaria Formation. Dikes up to 100 feet wide locally cut the Palmetto and Candelaria Formations and appear to be feeders for the sills. Mine intrusives predate mineralization and are themselves hydrothermally altered and weakly mineralized.

Major uplift occurred during the late Cretaceous to early Oligocene time. This event allowed for post-mineral shearing along mineralized structural zones and exposed the Candelaria mineralization to significant surface weathering and oxidation. Subsequently in Oligocene time, this deeply weathered erosional paleosurface was buried by ash-flow tuffs, with thicknesses up to 2,000 feet.

Miocene, Pliocene, and Recent age regional extensional tectonics resulted in "Basin and Range" normal faulting. This event is characterized by the relative uplift and erosion of ranges and the contemporaneous subsidence and alluvial filling of basins. Local volcanism resulted in a capping of basalt flows in the ranges.

Mineralization

Candelaria Mining District hosts epigenetic silver mineralization of early Cretaceous age, with quartz stockwork mineralization occurring in faulted and sheared zones related to the regional thrusting. Pre-mineral thrusts and thrust-related structures of the Lower Candelaria Shear and the Pickhandle Gulch Thrust provided the ground preparation for the introduction of hydrothermal fluids. Figure 2 shows a simplified geologic map of the Candelaria district and generalized geologic cross sections through the deposits.

The mineralized zones have been subjected to post-mineral shearing that has disrupted the mineralization. Subsequent weathering and oxidation of the mineralized zone occurred during two distinct periods of time. The first period of oxidation was during a late Cretaceous to early Tertiary erosional event, after which the paleo-erosional surface was capped by younger volcanic rocks. The second period followed the Tertiary to Recent erosional period during which the mineralized zones were again exposed at the surface. Partial to complete oxidation of the deposits extends down to depths of about 650 feet.

Within the Lower Candelaria Shear zone, sediments of Member 1 of the Candelaria Formation and associated intrusives show strong sericite alteration which bleaches the rock and obscures their original features, silicification in the form of quartz vein stockworks, and dolomitization (Thomson, 1990). Mineralization within the oxidized upper part of the Lower Candelaria Shear consists of fractured and partly brecciated gossanous sediments, which are riddled with small, irregular, milky white quartz veins, with ubiquitous coatings and impregnations of iron, with lesser manganese oxides. The iron oxides consist of hematite, goethite, limonite, and jarosite, as well as a variety of lead, zinc and copper secondary oxidation minerals, all derived from original sulfides. Silver occurs predominantly as native silver and in chlorargyrite, occurring as free grains ranging in size from a few microns to a few hundred microns (average size 10 to 40 microns). Locally in the oxidized zone, relict lenses of fresh sulfide- bearing material are preserved. The silver mineralization of the oxidized zones typically has a low gold content, with average ratios of 400 to 1 silver to gold. Within, and marginal to, the Lower Candelaria Shear zone are irregular and discontinuous high-grade lenses and shoots of more massive iron and manganese-iron oxides with dolomite and quartz gangue. These high-grade zones were the focus of early underground mining and consisted of lenses and shoots 2 to 10 feet thick, with strikes of

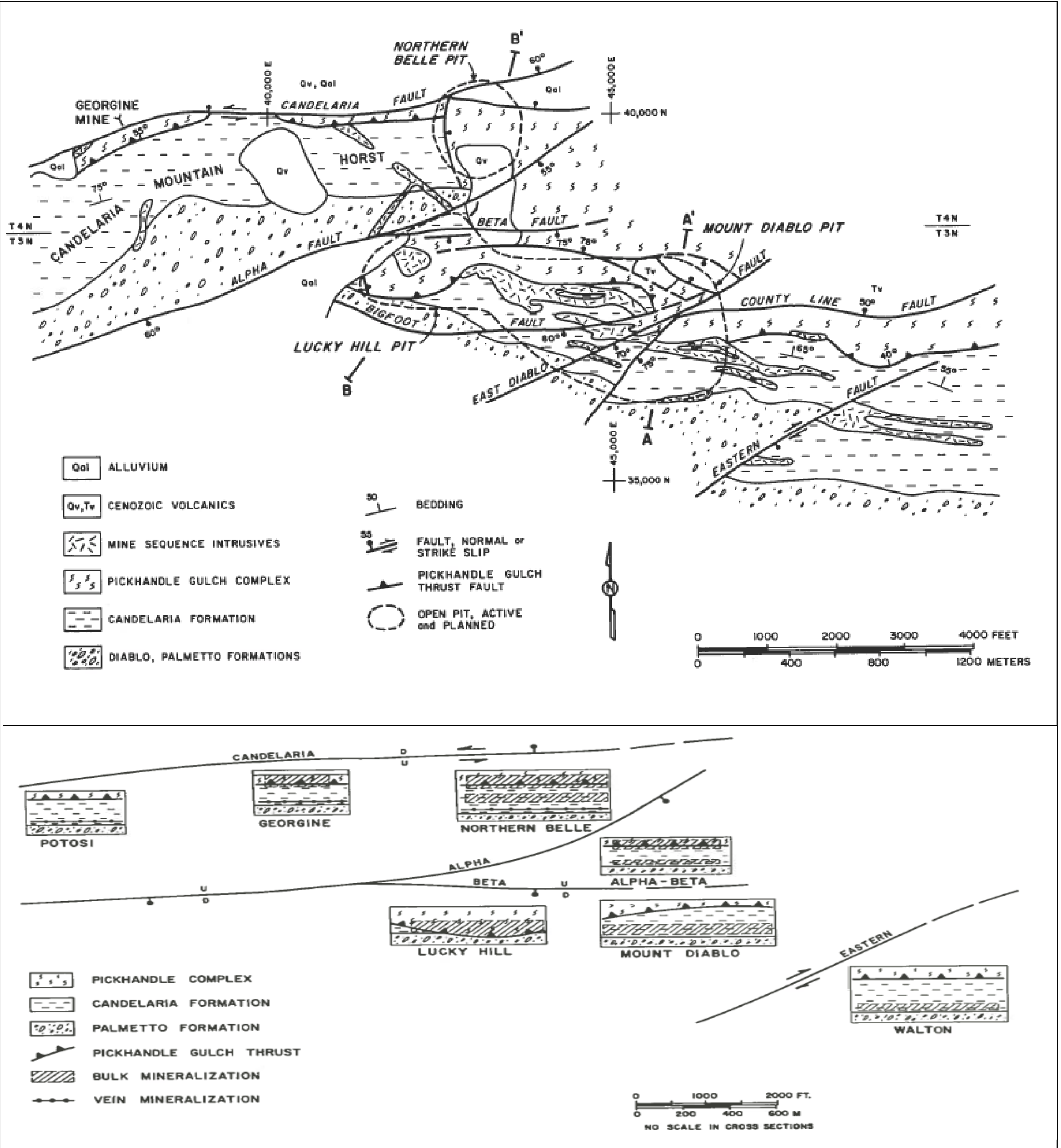


Figure 2 Generalized geologic map and cross-sections of the mine area (from Moeller, 1988)

up to 100 feet, and dip extents of several hundred feet. Many of the high-grade lenses may be the due to the replacement of narrow limestone beds that occur in Member 1 of the Candelaria Formation (Thomson, 1990). As in the surrounding oxidized shear zone, silver occurs predominantly as native silver and in chlorargyrite.

Above the Pickhandle Gulch Thrust, up to 260 feet of the Pickhandle Gulch Complex have been overprinted by quartz-dolomite alteration, which in places totally obscures the original character of the ultramafics (Thompson, 1990). Quartz stockworks are not as well developed in the Pickhandle Gulch Thrust zone. Mineralization in the oxidized upper part of the zone is contained in stockworks and fractures, with ubiquitous coatings and impregnations of manganese and lesser iron oxides. The manganese and iron oxides, as well as a variety of lead, zinc and copper oxides, are all derived from original sulfides. Nickel secondary minerals are characteristic in this zone. As in the mineralized Lower Candelaria Shear, silver occurs predominantly as native silver and in chlorargyrite, both occurring as free grains ranging in size from a few microns to a few hundred microns (average size 10 to 40 microns).

Below the oxidation zone, the Lower Candelaria Shear consists of a stockwork of narrow, white-grey pyritic quartz veins in black, sooty carbonaceous siltstones. Sulfides occur as disseminations, clots, and massive lenses of pyrite, with lesser jamesonite, tetrahedrite, stibnite, argentite/acanthite, covellite, with minor sphalerite, chalcopyrite, and galena. Except for covellite, these minerals all occur as inclusions encapsulated within pyrite and/or quartz. The maximum size of the base metal sulfide/sulfosalt inclusions is a few tens of microns. Silver occurs primarily as argentite inclusions in pyrite (Thomson, 1990).

High grade mineralization consists of crudely banded lenses of sulfides and gangue. Sulfides may be disseminated or may form discontinuous massive layers up to 2 feet thick. Sulfides include pyrite, sphalerite, galena, and jamesonite, with minor chalcopyrite and arsenopyrite. The gangue is mainly dolomite with lesser quartz. The high-grade sulfides typically range from 30 to 60 ounces of silver per ton. Silver appears to occur in galena and jamesonite, and as argentite, but its various occurrences are not well documented.

Below the zone of oxidation in the mineralized Pickhandle Gulch Complex (mainly exposed in the Northern Belle deposit), mineralization was reported from earlier underground mining to consist of crude banding of sulfides and gangue, hosted by sheared serpentinite and underlying carbonaceous siltstones, with local massive lenses of sulfides up to 1.5 feet thick. The sulfides consist primarily of pyrite, with lessor sphalerite, galena, and chalcopyrite, with minor amounts of jamesonite and arsenopyrite. Multiple generations of quartz and dolomite gangue are present (Moeller, 1988). Silver appears to occur in galena and jamesonite, and likely as argentite, but its various occurrences are not well documented.

Mineral Descriptions

The following are descriptions and photographs of the micro minerals that I have identified and collected during my time at the Candelaria Mining District.

Acanthite

A single, roughly crystalline mass in a cavity in quartz, from the Lower Candelaria Shear zone was found in drill cuttings from Drillhole N931, collared on the 5330 foot bench, Mount Diablo Pit. See Photo 1.

Photo 1. Acanthite, Drillhole N931. Scale bar = 1 mm. PKS Specimen No. 738

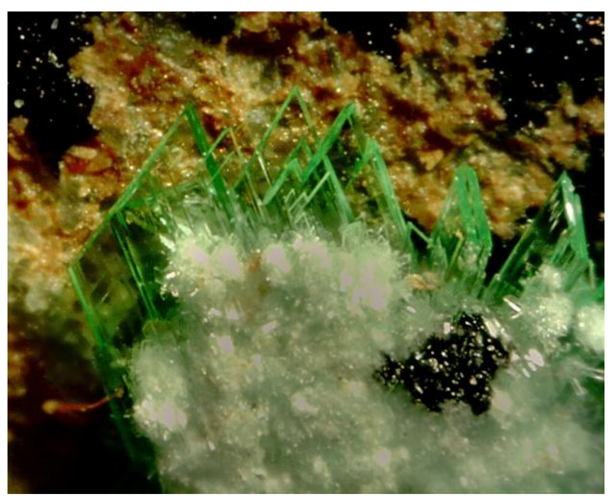


Photo 2. Annabergite from the 5830 foot bench, Mount Diablo Pit. FOV ~1.6 mm. PKS Specimen No. 756

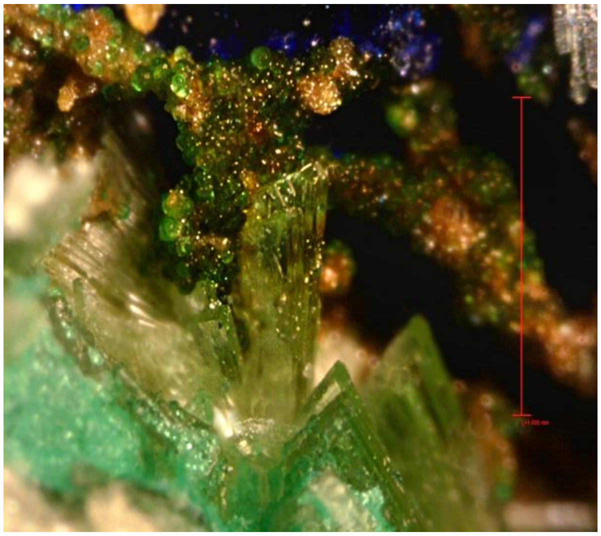


Photo 3. Annabergite with azurite and possible conichalcite from Mount Diablo Pit.
Scale bar = 1.0 mm. PKS Specimen No. 5091

Photo 4. Apatite. Scale bar = 1.0 mm.
PKS Specimen No. 704

Annabergite

Annabergite was found as discrete crystal groups and drusy crystal coatings on fractures in the Candelaria Formation just below the Pick-handle Gulch Thrust and as discrete crystals and coatings in the quartz-dolomite altered serpentinite of the Pickhandle Gulch Complex, all within the Mount Diablo Pit. Individual crystals up to 7.5mm in length were found. Photo 2 shows annabergite from fractures in the Candelaria Formation. Photo 3 shows a mixed assemblage from the Pickhandle Gulch Complex consisting of annabergite, azurite, possible conichalcite, and olivenite (not shown).

Apatite

Clear, prismatic crystals of apatite were found in fracture cavities in the Candelaria Formation east of the mine area in the Candelaria Hills. See Photo 4. Fluorapatite is found at the Potosi Mine as clear to white, hexagonal prisms.

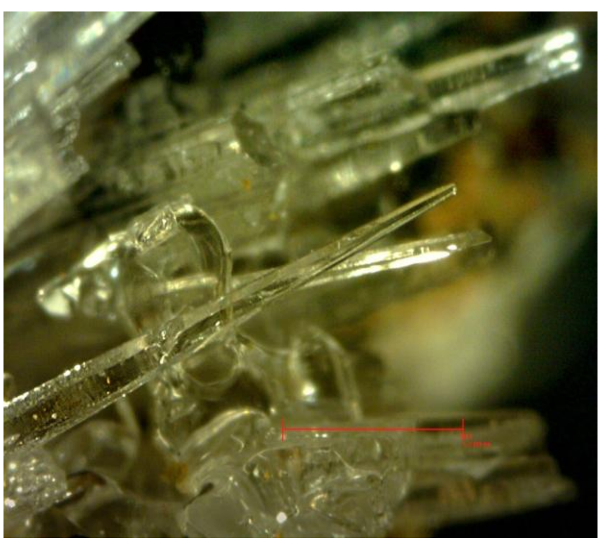


Photo 5. Aragonite with a tapered habit, 5810 foot bench, Mount Diablo Pit.
Scale bar = 1.0 mm. PKS Specimen No. 799

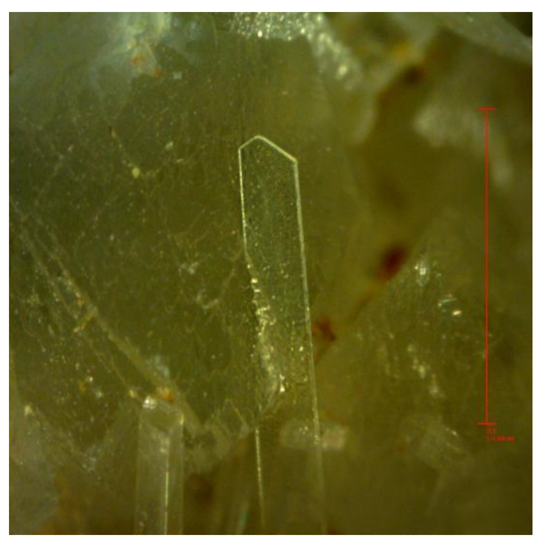


Photo 6. Aragonite with an elongate tabular habit; Mount Diablo Pit. Scale bar = 1.0 mm.
PKS Specimen No. 684

Aragonite

Transparent crystals were found in the Mount Diablo Pit and Georgine Mine. The habits observed are transparent, elongate sharply tapering to tabular crystals. See Photos 5 and 6.

Arsenopyrite

Sharp, bright crystals, frozen in quartz vein matrix were collected from the Georgine Mine. See Photo 7. Slightly oxidized crystals, also frozen in quartz vein matrix, were collected at the Hecla Mine.

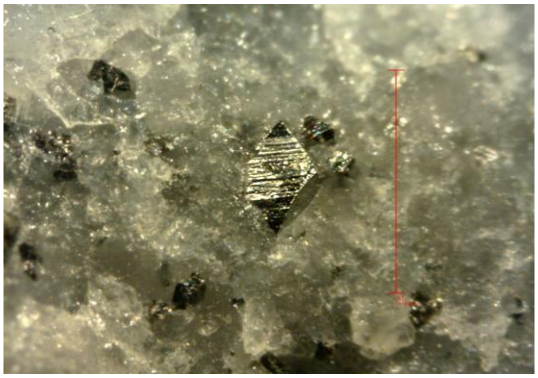


Photo 7. Arsenopyrite, Georgine Mine; Scale bar = 1.0 mm. PKS Specimen No. 2290

Azurite

Azurite was collected primarily from the Mount Diablo Pit. It occurs in the Candelaria Formation, the Pickhandle Gulch Complex, and in mineralized intrusive rocks. Color ranges from deep, nearly black azure blue to bright azure blue, with drusy crystal groups to single crystals. Associated frequently with olivenite and malachite in the Candelaria Formation and mineralized intrusive rocks, see Photos 8 and 9.

Photo 8. Double-terminated azurite with malachite from the Mount Diablo Pit. Scale bar = 1.0 mm. PKS Specimen No. 678

Photo 9. Single crystal on olivenite, Mount Diablo Pit. Scale bar = 1.0 mm. PKS Specimen No. 680

Cacoxenite

Yellow, acicular crystals forming spheres and "bow-ties" were collected from the Candelaria Formation within the Northern Bell Pit. Wavellite seems to be commonly associated with the cacoxenite. See Photo 10 and 11

Calcite

Calcite is fairly wide spread throughout the district. Nearly transparent, hexagonal prisms were collected from the Mount Diablo Pit (see Photo 12) as well as other forms, rhombic being the most common from other mines in the district.

Carminite

Minute, red crystals were found at the Potosi Mine and the Georgine Mine. Crystal habit varies from slender laths to stout aggregates of smaller crystals. See Photo 13.

Photo 10. Cacoxenite "bow-ties" from Northern Bell Pit. Scale bar = 1.0 mm. PKS Specimen No. 1795

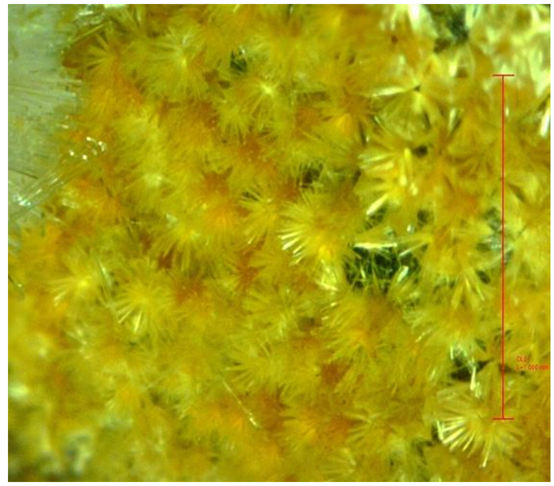


Photo 11. Clusters of Cacoxenite crystals with wavellite from Northern Belle Pit. Scale bar = 1.0 mm. PKS Specimen No. 1921

Photo 12. Hexagonal prism of calcite, Mount Diablo Pit. Scale bar = 1.0 mm. PKS Specimen No. 685

Photo 13. Carminite, 69 Level, Potosi Mine. Scale bar = 1.0 mm. PKS Specimen No. 2087

Photo 14. Chalcophanite, 5830 foot bench, Mount Diablo Pit. Scale bar = 1.0 mm. PKS Specimen No. 753

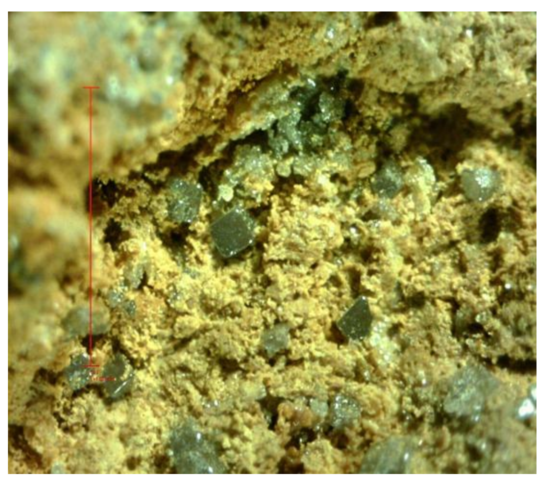


Photo 15. Chlorargyrite, Mount Diablo Pit. Scale bar = 1.0 mm. PKS Specimen No. 1506

Cerussite

Minute, transparent crystals were found at the Redbank Claim just to the east of Mount Diablo Pit. A small prospect on the claim contains a talc-carbonate-galena vein within Pickhandle Gulch Complex serpentinite. Cerussite was also found as minute crystals in the Mount Diablo Pit and the Potosi Mine.

Chalcophanite

Tabular, single crystals and rosettes were found associated with smithsonite on the 5830 foot bench of the Mount Diablo Pit. See Photo 14.

Chlorargyrite

Minute, cubic, gray-green crystals were found in a high grade pocket (~600 oz. per ton) in the Mount Diablo Pit. See Photo 15. Green crystalline masses were found in the Northern Bell Pit and Georgine Mine. Sharp green crystals are found at the Potosi Mine.

Galena

Minute, cubic to octahedral crystals were found in a quartz-carbonate vein in mineralized Pickhandle Gulch Complex serpentinite in the Mount Diablo Pit. See Photo 16. Discrete masses of galena are found in all the mines within the district.

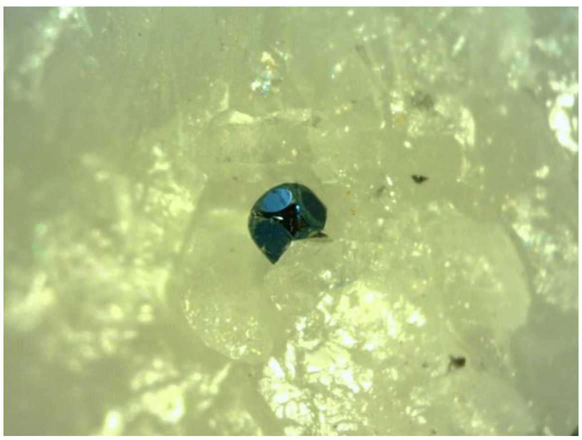


Photo 16. Galena with thin coating of covellite, 5810 foot bench, Mount Diablo Pit. FOV 1.6 mm.
PKS Specimen No. 768

Photo 17. Cube-octahedral galena crystal, 5810 foot bench, Mount Diablo Pit. Scale bar 1.0 mm.
PKS Specimen No. 2251

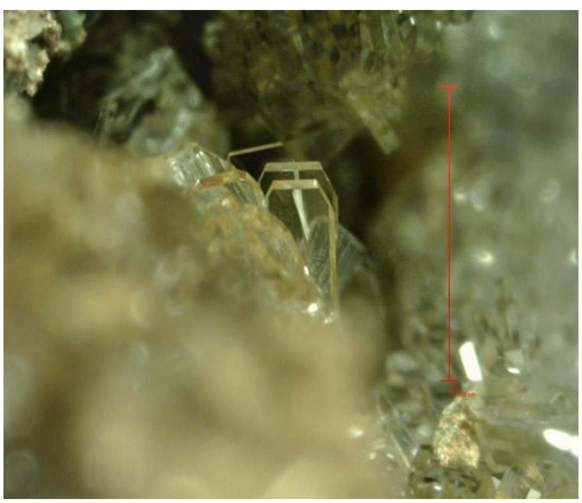


Photo 18. Hemimorphite, 5930 foot bench, Mount Diablo Pit. Scale bar = 1.0 mm. PKS Specimen No. 886

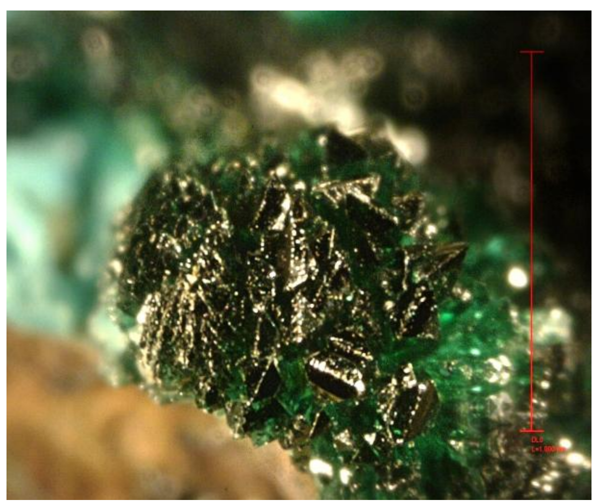


Photo 19. Libethenite, 6310 foot bench, Northern Belle Pit. Scale bar = 1.0 mm. PKS Specimen No. 686

Greenockite

Bright yellow crusts were found associated with quartz-pyrite-sphalerite veins in unoxidized Lower Candelaria Shear in the Mount Diablo Pit.

Hemimorphite

Clear, bladed crystals were found in the Mount Diablo Pit adjacent to smithsonite and chalcophanite occurrences. See Photo 18.

Jarosite

Clove-brown crystals to crystalline crusts were found in all the mines in the district. Potosi Mine had the most abundant and well formed crystals.

Libethenite

A single specimen of libethenite was found in the Candelaria Formation within the Northern Belle Pit. See Photo 19.

Malachite

Malachite was found to follow the same distribution as azurite in the district. Specimens of malachite with azurite and malachite pseudomorphs after azurite were found in Mount Diablo Pit. One specimen (see Photo 20) has clusters of single crystals of malachite.

Olivenite

Olivenite was found to occur mainly within Mount Diablo Pit, in both the Candelaria Formation and the Pickhandle Gulch Complex. Habits range from acicular (variety leucochalcite) (see Photo 21) to equant crystals (see Photo 22). Olivenite was commonly found to be in association with azurite, and makes very attractive specimens.

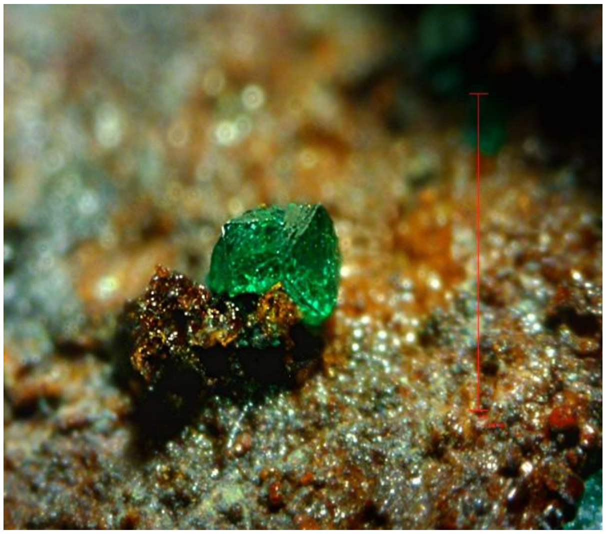


Photo 20. Two intergrown crystals of malachite, Mount Diablo Pit. Scale bar = 1.0 mm.
PKS Specimen No. 702

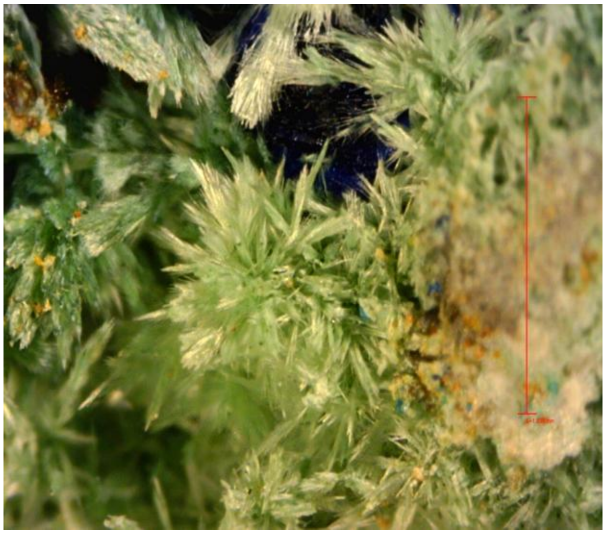


Photo 21. Olivenite, variety leucochalcite, with azurite from Pickhandle Gulch Complex, Mount Diablo Pit. Scale bar = 1.0 mm. PKS Specimen No. 5039

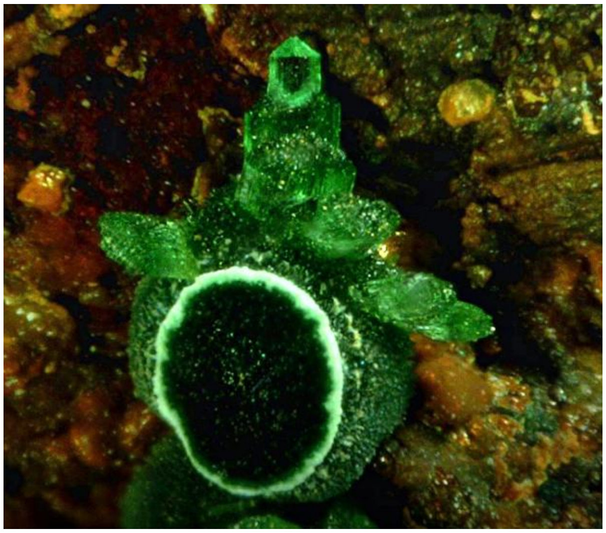


Photo 22. Olivenite, 5810 bench, Mount Diablo Pit. FOV 1.8 mm. PKS Specimen No. 786

Pyrite

Pyrite crystals were found in all mines of the district. Unoxidized cubic crystals were mainly found locked in quartz vein matrix. Mount Diablo Pit, Georgine Mine, and Potosi Mine produced nice micro crystals.

Pharmacosiderite

Pale green, pseudo-cubic micro crystals were found in Mount Diablo Pit (see Photo 23) and at the Georgine Mine (see Photo 24). Pharmacosiderite was associated with olivenite and azurite in the Mount Diablo Pit and scorodite and carminite at the Georgine Mine.

Photo 23. Pharmacosiderite, 5910 foot bench, Mount Diablo Pit. Scale bar = 1.0mm. PKS Specimen No. 885

Photo 24. Pharmacosiderite, Georgine Mine. Scale bar = 1.0 mm. PKS Specimen No. 2271

Scorodite

Pale green to pale blue crystals and crystalline masses of scorodite were found in abundance at the Potosi Mine and Georgine Mine. The Potosi Mine had the most well developed crystals, found in a massive quartz vein that represented the Lower Candelaria Shear Zone. See Photos 25 and 26.

Photo 25. Scorodite, 69 level, Potosi Mine. Scale bar 1.0 mm. PKS Specimen No. 787

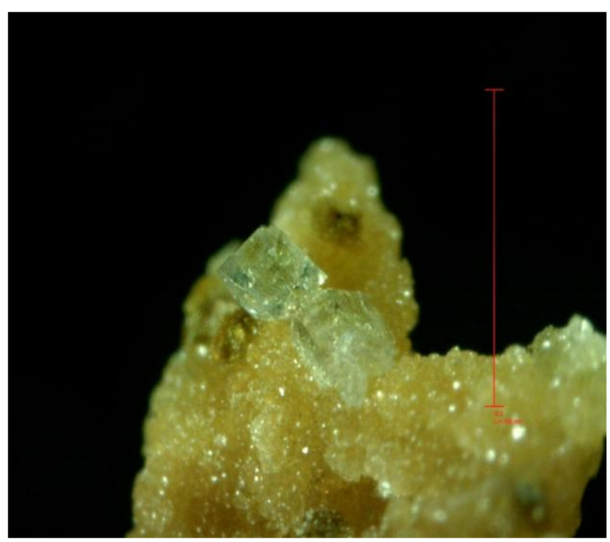


Photo 26. Scorodite, 69 level, Potosi Mine. Scale bar = 1.0 mm. PKS Specimen No. 789

Smithsonite

Green to pale yellow crystals/crystal aggregates of smithsonite were found in two locations within the Mount Diablo Pit, the 5830 foot bench in the Lower Candelaria Shear and in the north wall of the 5810 foot bench in quartz-carbonate vein cavities in the Pickhandle Gulch Complex. See Photo 27.

Sphalerite

Black micro crystals were found in quartz-carbonate veins in the Pickhandle Gulch Complex located in the Mount Diablo Pit. Dark brown sphalerite was also found frozen in quartz veins in the Northern Belle Pit and Georgine Mine.

Tourmaline Group

Dark to pale olive green crystals were found with quartz crystals in narrow veins within tourmalinized Candelaria Formation near Georgine Mine. See Photo 28.

Photo 27. Smithsonite, 5830 foot bench, Mount Diablo Pit. Scale bar = 1.0 mm. PKS Specimen No. 855

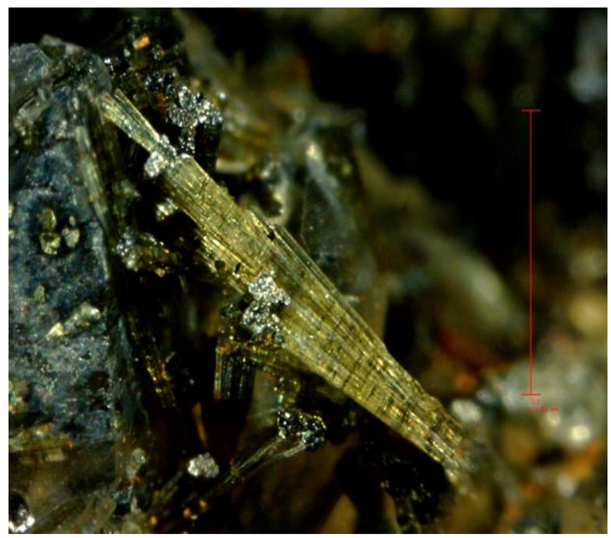


Photo 28. Tourmaline Group, Near Georgine Mine. Scale bar = 1.0 mm. PKS Specimen No. 898

Turquoise

Turquoise was found in Northern Belle Pit and in the Candelaria Hills to the southeast of the mine site. It was said that there were prehistoric workings for turquoise on the hillside that became the Northern Belle Pit. I found solid vein material suitable for jewelry and there were contractors hired to gathered up the turquoise when the mine was active. I was able to find botryoidal turquoise with wavellite and variscite that made some nice micro mounts. See Photo 29.

Variscite

Variscite was found as white spheres on botryoidal turquoise from the Northern Belle Pit. See Photo 30.

Wavellite

Elongated, transparent crystals of wavellite were fairly common in the Northern Belle Pit on joint and fracture surfaces in the Candelaria Formation. See Photos 31 and 32.

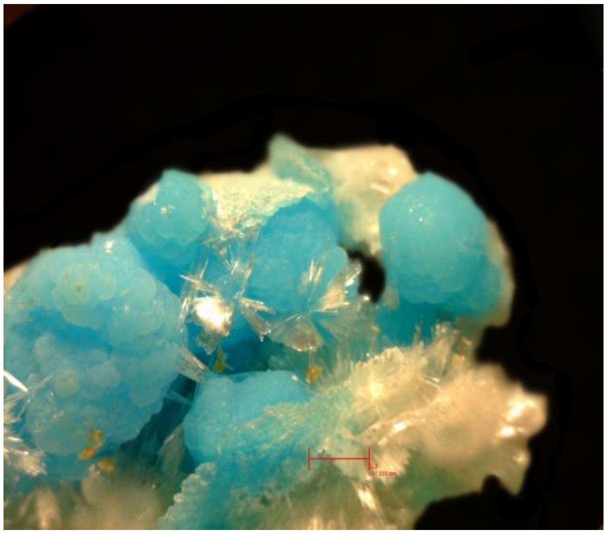


Photo 29. Turquoise with wavellite, Northern Belle Pit. Scale bar = 1.0 mm. PKS Specimen No. 1127

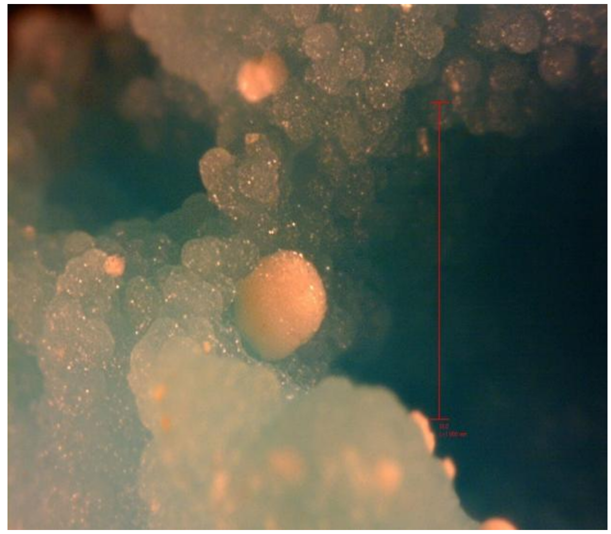


Photo 30. Variscite spheres on turquoise, Northern Belle Pit. Scale bar 1.0 mm. PKS Specimen No. 1128


Photo 31. Wavellite with cacoxenite, Northern Belle Pit. Scale bar = 1.0 mm. PKS Specimen No. 1921

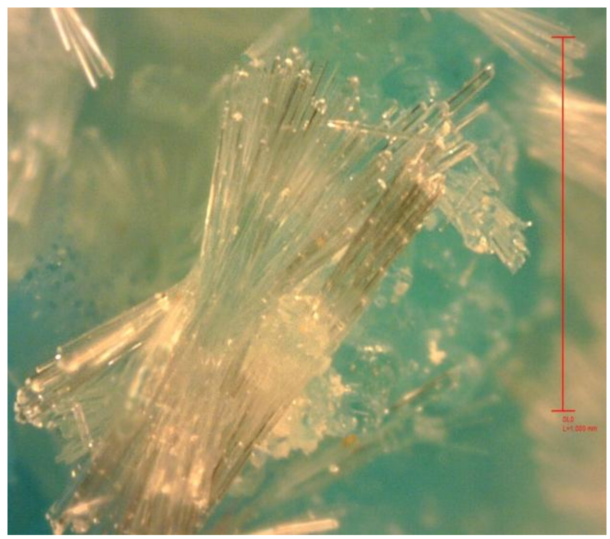


Photo 32. Wavellite on turquoise, Northern Belle Pit. Scale bar = 1.0 mm. PKS Specimen No. 1127

Digital Photography

All images in this article were taken with a Model AD-413T Dino-Lite digital microscope using a dual fiber optic illuminator. Helicon Filter software was used to process all images. Photo 22 was image stacked using Combine ZP software.

Bibliography

Moeller, S.A. 1988, Geology and Mineralization in the Candelaria mining district, Mineral County, Nevada: Geological Society of Nevada, Symposium on bulk mineable precious metal deposits of the Western United States, Reno, Nevada, April 6-8, 1987, Proceedings, p. 135-158.

Speed, R.C. 1984, Paleozoic and Mesozoic continental margin collision zone features: Mina to Candelaria, Nv. Transverse, *in* Lintz, Joseph Jr., ed., Western Geological Excursions v. 4, Geol. Soc. America Annual Mtg., Reno, Nevada, p. 66-80

Thomson, B. 1990, Geology of silver mineralisation at Candelaria, Nevada, USA: Unpublished Ph. D. Thesis, Aberdeen, United Kingdom, University of Aberdeen, 564 p.